где n - количество марок кирпича на печном вагоне, P_i - цена i-й марки, грн/тыс.шт., C_{s_i} - количество i-й марки на вагоне, тыс.шт.

Итак, полученные модели используются для прогноза и выдачи задания для системы автоматического регулирования расхода топлива, а также при создании системы статической оптимизации процесса обжига кирпича, что способствует существенному повышению качества готовой продукции и экономии топлива.

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PRODUCT LIFECYCLE MANAGEMENT IN CONSTRUCTION

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Розглядається життєвий цикл будівельного об'єкта та виокремлюються його основні етапи. На основі цього пропонується модель управління життєвим циклом продукту в будівництві, що включає його основні етапи та зв'язки між ними

Ключові слова: життєвий цикл будівельного об'єкта, PLM в будівництві

Рассматривается жизненный цикл строительного объекта, и выделяются его основные этапы. На основе этого предлагается модель управления жизненным циклом продукта в строительстве, которая включает его основные этапы и связи между ними

Ключевые слова: жизненный цикл строительного объекта, PLM в строительстве

In this paper we consider a construction object lifecycle. We distinguish the main stages of the construction object lifecycle and suggest a model of product lifecycle management (PLM) in construction

Key words: construction object lifecycle, PLM in construction

List of abbreviations

AEC	Architecture Engineering and Construction
CAD	Computer Aided Design
CAE	Computer Aided Engineering
CAM	Computer Aided Manufacturing
CAx	Computer Aided Technologies
CPD	Collaborative Product Development
DFMA	Design for Manufacturing and Assembly
DFSS	Design for Six Sigma
ETO	Engineering, Technology, Operations
HR	Human Resources
IT	Information Technologies
MPM	Manufacturing Process Management
NPD	New Product Development
PDM	Product Data Management
PLM	Product Lifecycle Management
PLM/AECO	PLM for Architects, Engineers, Construction Firms and Asset Owners

Introduction

Construction industry, especially, civil engineering, is one of the most needed in our lives. Every year more and more people need new homes. However, over the past two years construction industry has declined because of the world economic crisis. Despite this, construction still remains the most profitable industry. Many companies all over the world are involved in construction and all other industries related to it.

The final product of a construction is a building. From the industrial point of view, PLM is the process of managing the entire lifecycle of a product from its concept, through design and manufacture, to service and disposal. Providing an adequately high level of automated support to the entire lifecycle of a construction object is the important problem of today. In our century of high technologies most of stages of a construction process can be computerized. All computer-aided technologies used in PLM are combined by the term CAx. Today we have many different CAx tools which are used at all stages of construction industry. Some of these CAx tools are used only at one particular stage, while others can be used at several stages.

1. The Problem

Construction is a complex process which includes many stages. PLM process in construction, as in other industries, contains four main phases: conceive, design, realize, and service (conceptualization, design, and implementation). Each of these phases splits into several sub-phases. Today we have many IT-solutions for each of them. But we haven't many complex solutions for the construction object lifecycle. This article is a part of a global work which is dedicated to development of a methodology of creating universal extensible CAx tools for construction objects. Such kinds of IT-solutions will improve the entire construction process.

2. Analysis of recent research and publications

The term 'PLM' appeared on the edge of the centuries. Most of PLM solutions started developing at the beginning of the 21st century. Our range of interests is the PLM in construction.

Article [1] focuses on CAD education for students. The authors make a conclusion that just CAD is not enough. Nowadays students should study all CAx tools to have better chances to find a job.

Article [2] gives an explanation of the PLM concept. In this article the author comes to the conclusion that CAD, CAE, CAM are not good enough terms to accurately describe all what we are doing to create the final product in industry. So, he suggests calling all of it 'PLM'.

In article [3] the author considers ways to integrate PLM and production processes. He offers an integrated PLM-Automation solution to create a «closed loop» environment.

In article [4] the author explains a new direction of PLM products in construction called PLM/AECO. He reviews the PLM/AECO market and products and tries to make a forecast regarding their development in the future.

In article [5] the author offered an IT-solution to integrate CAx tools used in construction industry. He suggests creating a digital model of the object for storing all data about the construction object at any stage of its lifecycle.

3. Problem statement

In this paper we will consider every phase of the construction object lifecycle and break them into sub-phases. Also we will analyze each of these stages and determine the most useful CAx tools to be used at each of the stages. We will create a model of PLM in construction and determine the links between the stages. This model wills allows us to understand which data describing the construction object are the same and can be used at several phases of the construction object lifecycle.

4. Main research

PLM is a larger concept than the construction process. In fact, PLM consists of six elements. Each of these elements contains sub-level items (fig. 1).

According to the PLM structure, we have considered construction in different ways. We believe the basic PLM element for construction is the process. Each phase of a construction process can be linked with data, tools and people.

So, we distinguished the main PLM elements for construction. Next step of this work is breaking down each of the stages of construction process. Let's consider each of the stages separately.

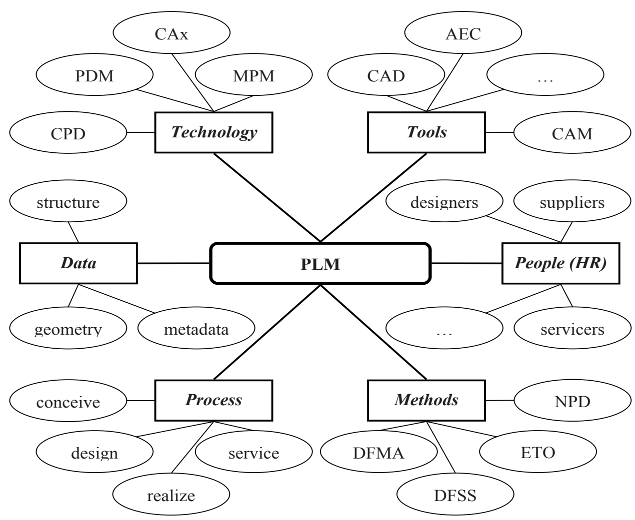

Fig. 1. PLM elements

As we said before, PLM as a process in construction consists of four main phases. The first phase is 'conceive' (imagine, specify, plan, and innovate). In construction, at this stage we generate an idea of a future building according to customer's requirements and building place peculiarities. Parallel to the requirements specification the initial concept design work is carried out defining the visual aesthetics of the product together with its main functional aspects. It could be accomplished with the help of many different tools, ranging from pencil and paper or clay models to 3D CAD software.

People who make this work usually are geodesists, architects and modelers. The data produced at this stage include generalized specifications, sketches and drawings of the design and models. Fig. 2 gives a schematic presentation of this phase.

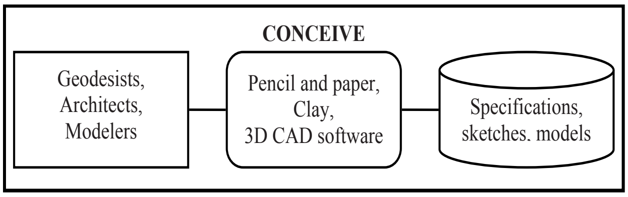

Fig. 2. PLM in construction first phase schema

The second phase of PLM in construction is design (describe, define, develop, test, analyze and validate). This is a very large stage which consists of many sub-phases. Some of them can be executed concurrently (in parallel), while others could be done only consecutively. But in any case most sub-phases are re-executed several times to ensure full design integrity. Buildings design includes designing a land profile, architectural design and structure calculation, internal and external engineering networks (sewage, water, heating, ventilation, electricity, and gas), ecological calculations (noise, illumination) and calculations of an estimated cost. Each of these processes is performed by different specialists. They use specialized CAx tools to do it. Every CAx tool uses its own data models of building, depending on the problem that needs to be solved. The breakdown of phase 2 is presented in table 1.

Table 1

PLM in construction second phase content

Sub-phase	Peoples	CAx tools	Data
1	2	3	4
Design land profile	Geodesist, Architect	Autodesk Civil 3D, CAD RELIEF	Digital map of relief, soil volume
Architecture design	Architect	ArchiCAD, AllPlan, Autodesk Revit Architecture	Geometry of all building elements, their topology, materials and attributes
Structure calculation	Design engineer	Autodesk Revit Structure, SCAD, LIRA, STARK ES	Geometry of construction elements, their topology and materials, force reactions
Internal and external engineering networks	Sanitary engineer, Electrical engineer	AutoCAD MEP, Autodesk Revit MEP	Full 3D model of building, geometry and topology of engineering networks, list of all networks items and their attributes
Ecology calculations	Environmental engineer	Autodesk Ecotect Analysis, BEES, EcoDesigner, Eco-Calculator	Full 3D model of building, materials properties, geographic placement, spaces configuration
Calculation of estimated cost	Quantity surveyor	BID2WIN Estimating & Bidding, AVK, TK-ISS	Volumes of each building element, materials prices, salaries

The third phase of PLM in construction is 'realization'. The building is constructed at this stage. The senior engineer manages construction with the help of drawings, specifications and estimated cost. He distributes material and financial resources according to these documents. We have some CAx tools to help him do it effectively. These tools were created specifically for construction management. They help senior engineers to plan the use of resources, project the period of construction and prepare all kinds of documentation using CAx tools. The schema of this phase is presented at fig. 3.

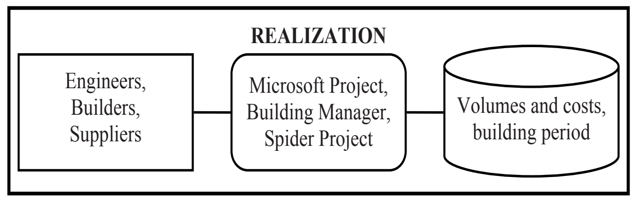

Fig. 3. PLM in construction third phase schema

The fourth phase of PLM in construction is 'service' (use, operate, maintain, support, retire, recycle and disposal). There are not so many CAx tools to support this stage of PLM in construction. This is because it's not necessary for this industry.

Based on previous research, we can merge phases and sub-phases which use CAx tools to create a model of PLM in construction.

The model, containing all basic stages and links between them is represented at fig. 4.

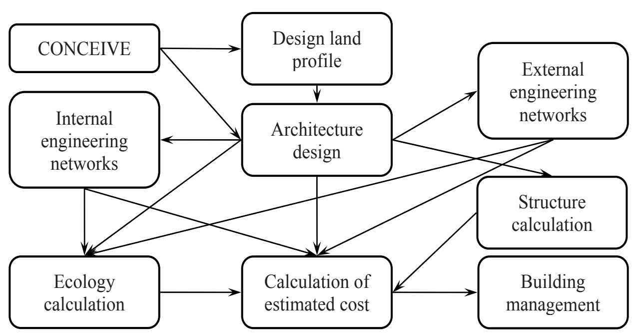

Fig. 4. Model of PLM in construction

The model of PLM in construction at figure 4 allows us to determine basic stages at which CAx tools are used. Based on this, we can distinguish common data models and tools which are used throughout the entire construction object lifecycle. This information is very helpful for the creation of universal extensible CAx tools for construction objects.

5. Conclusions

In this article we analyzed PLM in construction. A study of this problem allowed us to determine basic stages of construction and distinguish main CAx tools used at every stage. Based on this research, we created the model of PLM in construction. The next step in research is to analyze data structures at each stage of PLM to distinguish global basic data core.

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ОЦІНЮВАННЯ РІВНЯ ЗНАНЬ СТУДЕНТІВ В ПІДСИСТЕМІ КОНТРОЛЮ ЗНАНЬ МОДЕЛІ АДАПТИВНОГО НАВЧАННЯ

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Виконано аналіз існуючих методів контролю знань. Запропоновано структуру інтелектуальної (адаптивної) системи контролю знань, що містить контролюючий блок з аналізом результатів навчання (АРН)

Ключові слова: інформаційні технології, інтелектуальна система, адаптація, методи, тестовий контроль знань

Выполнен анализ существующих традиционных и современных методов контроля знаний. Предложена структура интеллектуальной (адаптивной) системы контроля знаний, которая имеет в структуре контролирующий блок с анализом результатов обучения (АРО)

Ключевые слова: информационные технологии, интеллектуальная система, адаптация, методы, тестовый контроль знаний

The analysis of existing traditional and modern methods of control knowledge. A structure of the intellectual (adaptive) supervisory system which has in a structure a supervisory block with the analysis of teaching results (ARO) is offered

Key world: information technology, intellect system, adaptation, methods, test control knowledge

1. Вступ

На сьогоднішній день як у школі, так і у вищому навчальному закладі (ВНЗ) все жорсткіше постає питання контролю знань. Тестовий контроль, який останнім часом приваблює все більшу увагу педагогів у різних сферах, - є універсальною формою контролю знань. Для його проведення використовуються як традиційні, так і сучасні методи. Серед останніх чи не найширше поширення знаходять методи контролю знань шляхом тестування.

Перевагу тестового контролю складає те, що він є науково-обґрунтованим методом емпіричного дослідження. На відміну від звичайних задач тестові